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Health and Environmental Effects Profile for Brominated Dibenzofurans

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HEALTH AND ENVIRONMENTAL EFFECTS PROFILE FOR BROMINATED DIBENZOFURANS

ENVIRONMENTAL CRITERIA AND ASSESSMENT OFFICE
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16. ABSTRACT

The Health and Environmental Effects Profile for brominated dibenzofurans was prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Solid Waste and Emergency Response to support listings of hazardous constituents of a wide range of waste streams under Section 3001 of the Resource Conservation and Recovery Act (RCRA) and to provide health-related limits for emergency actions under Section 101 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Both published literature and information obtained from Agency program office files were evaluated as they pertained to potential human health, aquatic life and environmental effects of hazardous waste constituents.

Quantitative estimates have been presented provided sufficient data are available. Existing data are insufficient to determine an Acceptable Daily Intake (ADI) or a carcinogenic potency factor for brominated dibenzofurans.

The Reportable Quantity (RQ) value of 1, 10, 100, 1000 or 5000 pounds is used to determine the quantity of a hazardous substance for which notification is required in the event of a relase as specified by CERCLA based on chronic toxicity. Existing data are insufficient to determine an RQ value.

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PREFACE

Health and Environmental Effects Profiles (HEEPs) are prepared for the Office of Solid Waste and Emergency Response by the Office of Health and Environmental Assessment. The HEEPs are intended to support listings of hazardous constituents of a wide range of waste streams under Section 3001 of the Resource Conservation and Recovery Act (RCRA), as well as to provide health-related limits for emergency actions under Section 101 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Both published literature and information obtained from Agency program office files are evaluated as they pertain to potential human health, aquatic life and environmental effects of hazardous waste constituents. The literature searched and the dates of the searches are included in the section titled "Appendix: Literature Searched." The literature search material is current through November, 1984.

Quantitative estimates are presented provided sufficient data are available. For systemic toxicants, these include Acceptable Daily Intakes (ADIs) for chronic exposures. An ADI is defined as the amount of a chemical to which humans can be exposed on a daily basis over an extended period of time (usually a lifetime) without suffering a deleterious effect. In the case of suspected carcinogens, ADIs are not estimated in this document series. Instead, a carcinogenic potency factor of q_1^* (U.S. EPA, 1980) is provided. These potency estimates are derived for both oral and inhalation exposures where possible. In addition, unit risk estimates for air and drinking water are presented based on inhalation and oral data, respectively.

Reportable quantities (RQs) based on both chronic toxicity and carcinogenicity are derived. The RQ is used to determine the quantity of a hazardous substance for which notification is required in the event of a release as specified under CERCLA. These two RQs (chronic toxicity and carcinogenicity) represent two of six scores developed (the remaining four reflect ignitability, reactivity, aquatic toxicity and acute mammalian toxicity).

The first draft of this document was prepared by Syracuse Research Corporation under EPA Contract No. 68-03-3228. The document was subsequently revised after reviews by staff within the Office of Health and Environmental Assessment: Carcinogen Assessment Group, Reproductive Effects Assessment Group, Exposure Assessment Group, and the Environmental Criteria and Assessment Office in Cincinnati.

The HEEPs will become part of the EPA RCRA and CERCLA dockets.

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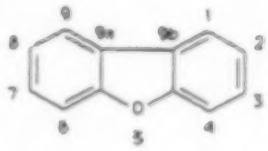
LIST OF ABBREVIATIONS

ADI	Acceptable daily intake
BCF	Bioconcentration factor
bw	Body weight
CAS	Chemical Abstract Service
GC	Gas chromatography
HAC	Glacial Acetic Acid
K_{oc}	Soil sorption coefficient
K_{ow}	Log octanol/water partition coefficient
LD_{50}	Dose lethal to 50% of recipients
LT_{50}	Median lethal time
PBB	Polybrominated biphenyl
PCB	Polychlorinated biphenyl
ppm	Parts per million
RQ	Reportable quantity
SCE	Sister chromatid exchange
TCDD	Tetrachlorodibenzo-p-dioxin

1. INTRODUCTION

1.1. STRUCTURE AND CAS NUMBER

Brominated dibenzofurans are compounds having structures obtained by substitution of hydrogen atoms with bromines at different benzene ring positions of dibenzofuran. The accepted system of numbering substituents to the dibenzofuran nucleus is as follows:



A total of 135 congeners of brominated dibenzofurans are structurally possible; however only a few of these congeners have been studied. The structure, empirical formula, molecular weight and the CAS Registry numbers of a few congeners are given in Table 1-1.

1.2. PHYSICAL AND CHEMICAL PROPERTIES

The physical and chemical properties of brominated dibenzofurans have not been well studied. The boiling point and vapor pressure values for only a few brominated dibenzofurans are known. Data pertaining to the aqueous solubilities of these compounds were not available in the literature as cited in the Appendix. The physical properties of a few brominated dibenzofurans are presented in Table 1-2. A few other physical properties that are necessary for the prediction of the environmental fate and transport of brominated dibenzofurans, but the values of which are not available, have been derived from predictive theories.

1.2.1. Predictive Theory.

1.2.1.1. OCTANOL-WATER PARTITION COEFFICIENT (K_{ow}) -- The Fragment Constant Method of Leo (Lyman et al., 1982) has been used to derive K_{ow} values for three model brominated dibenzofurans, 2,8-dibromo-, 1,2,7,8,-tetrabromo- and 2,3,7,8,-tetrabromodibenzofuran. The rationale for

TABLE 1-1

Structural Characteristics and CAS Registry Numbers for a Few Brominated Dibenzofurans

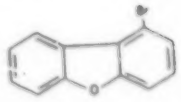
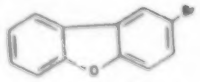
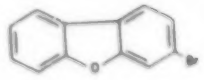
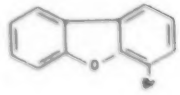
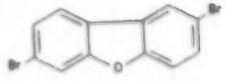
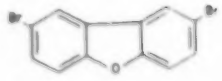
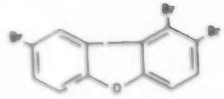
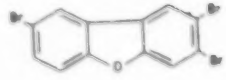
Name	Structure	Empirical Formula	Molecular Weight	CAS Registry Number
1-Bromodibenzofuran		$C_{12}H_7OBr$	246.96	NR
2-Bromodibenzofuran		$C_{12}H_7OBr$	246.96	86-76-0
3-Bromodibenzofuran		$C_{12}H_7OBr$	246.96	NR
4-Bromodibenzofuran		$C_{12}H_7OBr$	246.96	NR
2,7-Dibromodibenzofuran		$C_{12}H_6OBr_2$	325.86	65489-80-7
2,8-Dibromodibenzofuran		$C_{12}H_6OBr_2$	325.86	68795-14-2
1,2,8-Tribromodibenzofuran		$C_{12}H_5OBr_3$	404.75	84761-81-9
2,3,8-Tribromodibenzofuran		$C_{12}H_5OBr_3$	404.75	84761-82-0

TABLE 1-1 (cont.)

Name	Structure	Molecular Formula	Molecular Weight	CAS Registry Number
1,2,7,8-Tetrabromodibenzofuran		$C_{12}H_4OBr_4$	483.65	84761-80-8
2,3,7,8-Tetrabromodibenzofuran		$C_{12}H_4OBr_4$	483.65	67738-57-7

NR - Not reported

TABLE 1-2

Physical Properties of Selected Brominated Dibenzofurans

Brominated Dibenzofuran	Appearance	Solubility in Solvent(s)	Melting Point (°C)	Boiling[a] Point (°C)	Vapor Pressure (mm Hg)	λmax[b] (nm)	Reference
1-Bromo-	NR	NR	67	NR	NR	NR	U.S. EPA, 1982
2-Bromo-	colorless needles or leaflets	acetic acid, ethanol	110	220	40	310 (4680)	Weast, 1980; U.S. EPA, 1982
3-Bromo-	colorless leaflets	ethanol, ether	120	220	40	300 (16,600)	Weast, 1980; U.S. EPA, 1982
4-Bromo-	NR	NR	67-72	NR	NR	NR	Weast, 1980; U.S. EPA, 1982
2,8-Dibromo-	colorless leaflets	ethanol, ether, benzene, acetic acid	199-200	NR	NR	NR	Weast, 1980
1,2,8-Tribromo-[c] 2,3,8-Tribromo-[c]	colorless prisms	benzene, chloroform	144-148.5	NR	NR	NR	Tashiro and Yoshiya, 1982
1,2,7,8-Tetrabromo-	colorless needles	benzene, chloroform	240.5-242	NR	NR	NR	Tashiro and Yoshiya, 1982
2,3,7,8-Tetrabromo-	colorless needles	benzene, chloroform	301-302	NR	NR	NR	Tashiro and Yoshiya, 1982

[a]Measured at a pressure of 40 mm Hg

[b]The absorption maxima at longest wavelength. The values in the parentheses are the extinction coefficient.

[c]These two compounds could not be separated; therefore, the melting point given is for the mixture.

NR - Not reported

the selection of the two isomeric tetrabromo compounds is to demonstrate whether the predictive theories, in the case of such isomeric compounds, have the capabilities to predict different values for each individual parameter. A U.S. EPA on-line computer program with GEMS and CLOGP (calculated log P) has been used to estimate the K_{ow}. The estimated log K_{ow} values are 5.82, 7.55 and 7.55 for 2,8-dibromo-, 1,2,7,8-tetrabromo- and 2,3,7,8-tetrabromodibenzofuran, respectively. The limitation of the fragment constant method is that it is incapable of distinguishing the difference in K_{ow} values between isomeric compounds.

1.2.1.2. **WATER SOLUBILITY** -- The water solubilities of the three compounds have been determined from the estimated K_{ow} values and the following regression equation (Lyman et al., 1982):

$$\log S = -0.88 \log K_{ow} - 0.01\, t_m - 0.012,$$

where S is the water solubility in mol/ℓ, and t_m is the melting point of the compound in °C. The justifications for using this equation rather than several other correlation equations (Lyman et al., 1982) are that this equation is applicable for polyaromatic compounds, has a high correlation coefficient for the compounds tested and uses a variable parameter (t_m) for which experimental values are available, therefore, providing more realistic solubility values.

The application of the above equation using the t_m values given in Table 1-2 and the estimated K_{ow} values given in Section 1.2.1.1., results in aqueous solubility values of 24, 0.4 and 0.1 ppb for 2,8-dibromo-, 1,2,7,8- tetrabromo- and 2,3,7,8-tetrabromodibenzofuran, respectively.

1.2.1.3. **SOIL PARTITION COEFFICIENT STANDARDIZED WITH RESPECT TO SOIL ORGANIC MATTER CONTENT (K_{oc})** -- The K_{oc} values for the three compounds have been estimated from the following regression equation (Lyman et al., 1982): $\log K_{oc} = 0.937 \log K_{ow} - 0.006$.

With the estimated K_{ow} values given in Section 1.2.1.1., log K_{oc} values of 5.45, 7.07, and 7.07 have been calculated for 2,8-dibromo-, 1,2,7,8-tetrabromo- and 2,3,7,8-tetrabromodibenzofuran, respectively. The two tetrabromo isomers have the same estimated K_{oc} value because their k_{ow} values are the same due to the inability of the fragment constant method to distinguish between isomeric compounds.

1.2.1.3. **BIOCONCENTRATION FACTOR (BCF)** -- The following regression equation (Lyman et al., 1982) has been used to estimate the BCF values: log BCF = 0.76 log K_{ow} -0.23. Using the estimated log K_{ow}, log BCF values of 4.19, 5.51 and 5.51 have been estimated for 2,8-dibromo-, 1,2,7,8-tetrabromo- and 2,3,7,8-tetrabromodibenzofuran, respectively.

1.2.1.4. **SUMMARY OF ESTIMATED VALUES** -- In summary, the solubility, K_{ow}, K_{oc} and BCF values estimated from Leo's Fragment Constant Method and various regression equations are shown in Table 1-3. These values may be used in making predictions about the environmental fate of these chemicals. For comparison, the corresponding values for dichlorodibenzo-p-dioxin and 2,3,7,8-tetrachlorodibenzo-p-dioxin are also given. It should be emphasized that, with the exception of the water solubility values for 2,3,7,8-tetrachlorodibenzo-p-dioxin, all other values given for chlorinated dibenzo-pdioxins are estimated (U.S. EPA, 1984; NRCC, 1981).

1.2.2. **Chemical Properties.** Lower brominated dibenzofurans yield litho compounds by interchange with lithium salts, and can be brominated to higher brominated dibenzofurans (see Section 1.3.). The monobromodibenzofurans can be nitrated at different ring positions with nitrating agents. 2,8-Dibromodibenzofuran can react with ammonia under pressure and in the presence of a copper catalyst (U.S. EPA, 1982). Although the photodecomposition of

TABLE 1-3

Selected Parameters for Three Brominated Dibenzofurans
Estimated from Predictive Theories

Compound	log K_{ow}	Solubility (µg/ℓ)	log K_{oc}	log BCF
2,8-Dibromo-dibenzofuran	5.82	24	5.45	4.19
1,2,7,8-Tetrabromo-dibenzofuran	7.55	0.4	7.07	5.51
2,3,7,8-Tetrabromo-dibenzofuran	7.55	0.1	7.07	5.51
Dichlorodibenzo-p-dioxin	4.71	6	4.60	3.30
2,3,7,8-Tetrachloro-dibenzo-p-dioxin	6.15	0.2	6.0	4.53 (3.30-4.48)*

*The values in parentheses are the range of experimentally determined BCF values (U.S. EPA, 1984).

brominated dibenzofurans has not been studied, debromination of brominated dibenzofurans is possibly one of the reactions that may be environmentally significant.

1.3. PRODUCTION AND SOURCE DATA

None of the brominated dibenzofurans are commercially manufactured in the United States. Between 1971 and 1974, Michigan Chemical Corp., St. Louis, MO, produced 11.8 million pounds of PBBs under the trade names, Firemaster BP-6 and Firemaster FF-1, which are primarily used as fire retardants for plastic components of electrical appliances and business machines. Both commercial FF-1 and BP-6 are similar products (commercial FF-1 is BP-6 mixed with 2% calcium silicate) (DiCarlo et al., 1978). Hass et al. (1978) reported that commercial BP-6 contained ~13 congeners of PBB. The largest individual constituent of BP-6 was 2,4,5,2',4',5',-hexabromobiphenyl, which along with two other hexabromobiphenyls represented 62.6% of all PBBs presents. The remaining PBBs consisted of 4% of two isomeric pentabromobiphenyls and 33.4% of three isomeric heptabromobiphenyls, (Hass et al., 1978). No bromodibenzofuran or dibenzo-p-dioxin was found in any of the commercial products at a detection limit of 0.5 ppm (Hass et al., 1978).

O'Keefe (1978) pyrolized Firemaster FF-1 in contact with air at a temperature of 380-400°C for 20 minutes. About 40 ppm of 2,3,7,8-tetrabromodibenzofuran, 4 ppm of an unspecified pentabromodibenzofuran, and approximately 3ppm of the impurity, hexabromonaphthalene, were detected in the pyrolyzed products. When the pyrolysis was carried out in nitrogen atmosphere, however, only a weak mass-spectrometric signal (amount not quantified) for tetrabromodibenzofuran was detected. Buser et al. (1978) reported that although Firemaster BP-6 was completely destroyed at 700°C,

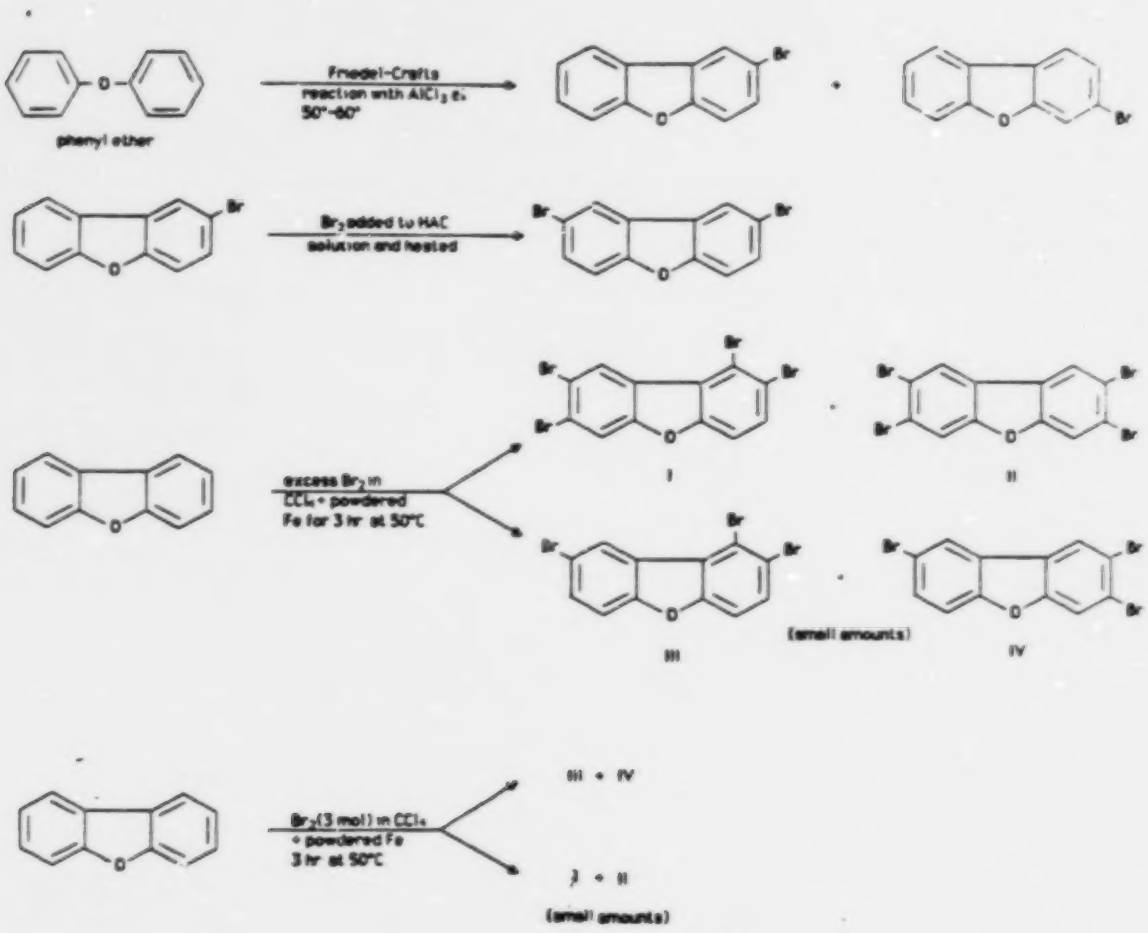
pyrolysis of Firemaster BP-6 at a temperature of 600°C probably forms 2,3,7,8-tetrabromodibenzofuran in amounts which may range from 0.2-1.6% of the parent compound.

A metabolite of Firemaster BP-6 extracted from dog feces, 6-hexahydroxy-2,4,5,2',4',5'-hexabromobiphenyl, decomposed in a OV-101 GC column heated at 230-260°C to form 1,3,4,7,8-pentabromo- and 1,3,4,6,7-pentabromodibenzofuran (Gardner et al., 1979). Therefore, incineration of animals contaminated with PPBs may produce brominated dibenzofurans.

The likely sources of brominated dibenzofurans in the environment can be inferred from the previous discussion. Although no brominated dibenzofurans have been detected at levels >0.5 ppm in PPBs, they may still contain the brominated dibenzofurans at levels <0.5 ppm; however, the discontinued use of PBBs eliminates new emissions of brominated dibenzofurans from this source. Brominated dibenzofurans may be released into the environment when electric appliances and business machines which contain Firemaster BP-6 or Firemaster FF-1 as a fire retardant are incinerated. Another potential source may be in the incineration of animals contaminated with PBBs which occurred in the Michigan accident (Shah, 1978). This source may be considered nonexistent at the present time since there are no new cases of animals contaminated with PBBs.

From 1970 until early 1977, White Chemical Co. of Bayonne, NJ and Hexcel Corp. of Sayreville, NJ produced ~1.54 million pounds of octabromo- and decabromobiphenyl (DiCarlo et al., 1978). The possibility of production of brominated dibenzofurans either during the production, usage or incineration of the above chemicals has not been investigated.

A few of the brominated dibenzofurans have been synthesized in the laboratory and the methods used (Keumi et al., 1972; Tashiro and Yoshiya, 1982; Cullinane et al., 1934) are given below:



1.4. USE DATA

There is no known commercial use for any of the brominated dibenzofurans.

2. ENVIRONMENTAL FATE AND TRANSPORT PROCESSES

Few experiments have been performed relating to the fate and transport of brominated dibenzofurans in the environment. The following inferences regarding the fate of these compounds are based on the estimated physical parameters given in Section 1.2. and the fate and transport of polychlorinated dibenzo-p-dioxins in the environment (U.S. EPA, 1984). In aquatic media, these compounds may be resistant to biodegradation, and neither oxidation nor hydrolysis are likely to be significant fate processes. In the absence of hydrogen donors, significant aquatic photolysis of these compounds is also unlikely. Based on experimental results obtained with chlorinated dibenzofurans (U.S. EPA, 1982) the rate of photolysis for lower brominated dibenzofurans in the presence of hydrogen donating substrates may be slower than the higher brominated dibenzofurans. Evaporation from water may play some role in determining their fate in aquatic media, but considering the estimated high log K_{oc} value given in Table 1-3, sorption onto suspended particulate matter and sediment may play prominent roles in determining the fate of these chemicals. In the absence of any known mechanism that is likely to remove these chemicals from sediment, they may persist for a long period of time. Bioconcentration of these chemicals in aquatic organisms is expected to be significant. Based on the estimated log BCF values given in Table 1-3, the bioconcentrations for the brominated dibenzofurans are likely to be even higher than the corresponding chlorinated dibenzo-p-dioxins.

In the atmosphere, the brominated dibenzofurans are likely to be present in the particulate-sorbed phase, and the primary removal mechanisms from the atmosphere are expected to be wet and dry deposition.

In soils, brominated dibenzofurans may persist for a long time, since significant biotransformation or phototransformation of these compounds are not likely. Because their estimated water solubilities are lower and their estimated soil sorption capabilities are higher than those of the corresponding chlorinated dibenzo-p-dioxins (see Table 1-3), the leachability of these compounds from soil is expected to be even lower than that of the chlorinated dibenzo-p-dioxins.

3. EXPOSURE

No brominated dibenzofurans have ever been found in environmental samples. Since the industrial production of chlorinated phenols is known to produce some polychlorinated dibenzofurans as impurities (U.S. EPA, 1982), the production of brominated phenols may similarly produce polybrominated dibenzofurans as contaminants. Therefore, environmental samples surrounding the brominated phenol production sites would most likely contain detectable levels of polybrominated dibenzofurans.

4. PHARMACOKINETICS

4.1. ABSORPTION

Pertinent data regarding the absorption of the brominated dibenzofurans were not located in the available literature cited in the Appendix. Data on the absorption of the polychlorinated derivatives of the dibenzofurans also were not found. The polychlorinated dibenzo-p-dioxin, 2,3,7,8-TCDD, was absorbed by the oral route in laboratory animals to extents varying 50-86% with more efficient absorption observed when the compound was administered by gavage in an oily vehicle as compared with administration through the diet (U.S. EPA, 1984). When the compound was administered in soil, absorption was even further inhibited. Dermal absorption of 2,3,7,8-TCDD also demonstrated vehicle dependence, with the more hydrophobic vehicle inhibiting absorption. Absorption to soil or activated carbon sharply reduced or completely eliminated dermal absorption, respectively. The physical and chemical properties of the brominated dibenzofurans are similar to those of the polychlorinated dibenzo-p-dioxins, and it is expected that the analogous congeners will be absorbed similarly.

4.2. DISTRIBUTION

Pertinent data regarding the distribution of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. The data reported (U.S. EPA, 1982) for the polychlorinated dibenzofurans, a mixture of tetra, penta, and hexa isomers, indicated that the liver was a major deposition site for these compounds in rats. The rate of disappearance from the liver varied depending on the congeners with half-lives of 2 weeks reported for the mixture and 1.25 days reported for 2,3,7,8-tetrachlorodibenzofuran. It was also reported that the above mixture of polychlorinated dibenzofurans was distributed to only a limited

extent to the fetuses of pregnant mice, and that transfer to the young through the milk during nursing was more extensive.

Bleavins et al. (1981) compared the tissue distribution of PCBs and PBBs in pregnant mink and ferrets. The respective compounds were administered to the animals as radiolabeled material by intravenous injection. In the dams, higher levels of PBB than PCB were detected in the livers (5- to 10-fold), while similar levels were observed in the kidneys. In adipose tissue, the concentration pattern was reversed with a 2- to 8-fold greater level of PCB as compared to PBB reported. The ratio of the concentration of PBB:PCB in amniotic fluid of the mink was 0.14:0.33 and in the last trimester fetus of ferrets was 0.11:0.42, respectively. In 2-week-old mink, however, the concentration of PBB was 22.5-fold higher than PCB, reflecting a greater excretion of PBB in the maternal milk. The differences observed in this study may be related to the use of Aroclor 1242, which consists predominantly of lower chlorinated products as the source of the PCBs, while a mixture of 2,4,5,2',4',5'-hexa- and 2,3,4,5,2',4',5'-heptabromobiphenyl was the PBB source. As a result of the differences observed in the distribution of PCBs as compared with PBBs, it may be expected that some differences might occur in the distribution of the respective brominated and polychlorinated dibenzofurans.

4.3. METABOLISM

Pertinent data regarding the metabolism of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. No data were found specifically regarding the metabolism of the polychlorinated dibenzofurans in U.S. EPA (1982); however, excretion data suggested that 2,3,7,8-polychlorinated dibenzofuran was metabolized more rapidly than 2,3,7,8-TCDD.

4.4. EXCRETION

Pertinent data regarding the excretion of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. The U.S. EPA (1982) reported that the primary excretion route for the polychlorinated dibenzofurans was through the bile and feces. In rats, the rate of excretion of 2,3,7,8-tetrachlorodibenzofuran was more rapid than that of 2,3,7,8-TCDD, with estimated half-lives of <2 days and 3-5 weeks, respectively. The half-lives of 2,3,7,8-tetrachlorodibenzofuran in the monkey and guinea pig were estimated to be 8 and >20 days, respectively. These data suggest a similar qualitative pattern for the elimination of the polychlorinated dibenzo-p-dioxins and the brominated dibenzofurans although quantitative differences are apparent. Similarly, it is expected that the brominated dibenzofurans would have an excretion pattern similar to that described above, although quantitative estimates of the rate of excretion would be more tentative.

5. EFFECTS

5.1. CARCINOGENICITY

No studies of the potential carcinogenicity of the brominated dibenzofurans were located in the available literature as cited in the Appendix, and these chemicals are not scheduled for testing by the NTP (1984). In addition, no studies were located regarding the carcinogenic potential of any of the analogous polychlorinated derivatives of dibenzofuran (U.S. EPA, 1982). Some of the analogous polychlorinated dibenzo-p-dioxins have been shown to be carcinogenic in laboratory animals (U.S. EPA, 1984). 2,3,7,8-TCDD has been demonstrated to produce liver tumors or tumors at other sites in both rats and mice. A mixture of 1,2,3,6,7,8- and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin also produced liver tumors in mice and rats (U.S. EPA, 1984). A lower chlorinated dibenzo-p-dioxin, 2,7-dichlorodibenzo-p-dioxin, was not carcinogenic in rats and mice in a chronic 2-year feeding study however, 2,8-dichlorodibenzo-p-dioxin was carcinogenic to male B6C3F1 mice (NTP, 1979). As a result of similarities in structure between the brominated dibenzofurans and the polychlorinated dibenzo-p-dioxins, it is possible that some of the congeners of the brominated dibenzofurans may prove to be animal carcinogens.

5.2. MUTAGENICITY

Pertinent data regarding the mutagenicity of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. Similarly very little data on the polychlorinated dibenzofurans were located. The U.S. EPA (1982) reported a single study of the mutagenic potential of 2,3,7,8-tetrachlorodibenzofuran in bacterial systems. Using both the reverse mutation assays employing Salmonella typhimurium and the rec assay using Bacillus subtilis, 2,3,7,8-tetrachlorodibenzofuran produced negative results. In an analysis of SCE in Chinese hamster lymphocyte

culture a mixture of polychlorinated dibenzofurans, consisting of compounds with three to six chlorines, produced positive results. These data are consistent with the poor response observed in short-term genotoxicity assays for the related group of compounds, the polychlorinated dibenzo-p-dioxins.

5.3. TERATOGENICITY

Pertinent data regarding the teratogenicity of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. No data were available on the teratogenicity of the related polychlorinated dibenzofurans; however, U.S. EPA (1982) reported that tests on tetrachlorophenol and pentachlorophenol, which are assumed to or documented to contain polychlorinated dibenzofurans, have been able to demonstrate a teratogenic response resulting from contamination with polychlorinated dibenzofurans. The related polychlorinated dibenzo-p-dioxin, 2,3,7,8-TCDD, has been tested as a pure compound and has been shown to be teratogenic in rats, mice and rabbits (U.S. EPA, 1984).

5.4. OTHER REPRODUCTIVE EFFECTS

Pertinent data regarding the reproductive effects of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. Also, no studies on the reproductive effects of the polychlorinated dibenzofurans in females were found (U.S. EPA, 1982). Fetotoxicity has been observed for the polychlorinated dibenzo-p-dioxin, 2,3,7,8-TCDD, at doses in the low µg/kg bw range for rats, mice, rabbits, ferrets and monkeys. In addition, an unidentified congener of hexachlorodibenzo-p- dioxin was feticidal to rats during gestation days 6-15 at doses as 10 µg/kg bw (U.S. EPA, 1984).

In male rats fed diets containing 0, 1 and 10 ppm of a mixture of polychlorinated dibenzofurans, there was a significant decrease in testosterone levels in the high dose group (U.S. EPA, 1982).

5.5. CHRONIC TOXICITY

Pertinent data regarding the chronic toxicity of the brominated dibenzofurans were not located in the available literature as cited in the Appendix. Also no chronic toxicity data were available on the polychlorinated dibenzofurans (U.S. EPA, 1982). Some of the congeners of the related polychlorinated dibenzo-p-dioxins have been demonstrated to result in frank toxic effects in chronic oral studies at dose levels in the low µg/kg bw/day range (U.S. EPA, 1984). In rats and mice, adverse effects were primarily observed in the liver while in monkeys the observations included body weight loss, subdermal edema, bone marrow degeneration and histopathologic changes in the salivary gland, bile duct, lung and stomach. 2,7-Dichlorodibenzo-pdioxin, however, only produced mild toxic effects (decreased rate of body weight gain) in rats and mice maintained for ~2 years on diets containing 5000 and 10,000 ppm of the compound (NTP, 1979). By analogy, some of the congeners of the brominated dibenzofurans may also be toxic at low doses while other congeners are likely to be considerably less toxic.

5.6. OTHER RELEVANT INFORMATION

Very little data regarding the effects of the brominated dibenzofurans were located in the available literature as cited in the Appendix. Moore et al. (1979) determined a lethal dose for 2,3,7,8-tetrabromodibenzofuran in guinea pigs. Groups of six male Hartley guinea pigs were treated with a single oral dose at levels of 0, 0.47, 1.58, 4.74 and 15.8 µg/kg bw and observed for 30 days. Animals were weighted 3 times weekly and gross and

histological examinations were performed on all animals dying before the end of observation period as well as one from each of the lower dose groups. At the 4.74 and 15.84 µg/kg dose 1/6 and 6/6 animals died, respectively, with deaths occurring ~11 days after treatment in the high dose group. No deaths or body weight effects were observed in guinea pigs that received the 0.47 or 1.58 µg/kg dose of TBDF. Decreased body weight gain was recorded in the five guinea pigs that survived the 4.74 µg/kg dose. No hematologic or serum protein alterations were apparent in guinea pigs that survived the 30-day observation period and the only histologic finding was a mild thymus lymphoid hypoplasia. Gross and histologic examination of moribound or dead animals revealed immediate weight loss, marked reduction in the mass of the thymus, lack of body fat and muscle, adrenal hemorrhages, hyperplasia of epithelial cells in the kidney and urinary tract, and hypercellularity of the bone marrow, seminiferous tubules and lymphoid elements of the spleen. The lethal dose (15.84 µg/kg) falls into the same range on a molar basis, as that determined for 2,3,7,8-tetrachlorodibenzofuran and the signs of toxicity were identical. 2,3,7,8-TCDD also produced similar signs of toxicity in male Hartley guinea pigs although the LD_{50} for this compound was reported to be between 0.6 and 2.0 µg/kg (U.S. EPA, 1984).

6. AQUATIC TOXICITY

Data regarding the toxic effects of the various brominated dibenzofurans to aquatic organisms were not located in the available literature as cited in the Appendix: however, a limited amount of information of the toxic effects and residual concentration of the polychlorinated dibenzofurans were located. The potential effects of the brominated dibenzofurans on aquatic organisms can be inferred from an analysis of the effects of the polychlorinated dibenzofurans.

6.1. ACUTE TOXICITY

The only information concerning acute toxicity of polychlorinated dibenzofurans to aquatic organisms was provided by Zitkow et al. (1973) who reported that no mortality resulted after immature brook trout, Salvelinus fontinalis, were administered a single oral dose of 122 mg/kg 2,8-dichlorodibenzofuran.

6.2. CHRONIC TOXICITY

Data regarding the chronic toxicity of chlorinated dibenzofurans were located for two species of fish and one species of aquatic invertebrate. Zitkow and Choi (1973) fed a group of 35 juvenile Atlantic salmon, Salmo salar, dry fish food containing a mixture of di-, tri-, tetra- and octachlorodibenzofuran several times daily for 140 days. The measured concentration of each compound in the food was 2.1, 4.4, 2.2 and 9.7 µg/g, respectively. Control fish fed with uncontaminated food suffered no mortality. The LT_{50} for exposed fish was 120±30 days. Mortality in the exposed group reached 80% by the end of the 140-day exposure period.

Zitkow et al. (1973) conducted long-term feeding experiments with immature brook trout, Salvelinus fontinalis, using 2,8-dichlorodibenzofuran in

gelatin capsules. No toxic effects were observed in fish given a cumulative dose of 107-361 µg/g bw over an exposure period of ~100 days.

Fingerman and Fingerman (1977) investigated the effects of 1,2,3,4,5,6,7,8-octachlorodibenzofuran on the rate of molting of fiddler crabs, Uca pugilator, over a 38-day exposure period. Groups of crabs which were induced to molt by removal of four walking legs or both eyestalks were exposed to a concentration of 0.016 µg/ℓ octachlorodibenzofuran in artificial seawater or to uncontaminated medium. The cumulative percent molting in treated crabs was decreased by 11% in crabs without walking legs and by 23% in crabs without eyestalks, relative to the respective controls.

6.3. PLANT EFFECTS

Data regarding the effects of brominated or chlorinated dibenzofurans on aquatic plants were not located in the available literature as cited in the Appendix.

6.4. RESIDUES

Although no information concerning the uptake and depuration rates of any substituted dibenzofuran is available, there is evidence that chlorinated dibenzofuran has an affinity for lipid rich tissues of aquatic organisms. Zitkow and Choi (1973) reported that accumulation of octachlorodibenzofuran from food was higher in the gut than in the muscle of Atlantic salmon. The percent lipid composition was nearly three times higher in the gut than in the muscle. Zitkow et al. (1973) reported that accumulation of dichlorodibenzofuran from food was higher in the liver than in the muscle of brook trout; the liver contained lipid concentrations 3-36 times higher than muscle.

7. EXISTING GUIDELINES AND STANDARDS

7.1. HUMAN

Pertinent guidelines and standards, including EPA ambient water and air quality criteria, drinking water standards, FAO/WHO ADIs, EPA or FDA tolerances for raw agricultural commodities or foods, and ACGIH, NIOSH or OSHA occupational exposure limits were not located in the available literature as cited in the Appendix.

7.2. AQUATIC

Guidelines and standards for the protection of aquatic organisms from the toxic effects of the various brominated dibenzofurans were not located in the available literature as cited in the Appendix.

8. RISK ASSESSMENT

Pertinent data regarding the carcinogenicity, mutagenicity, teratogenicity or chronic toxicity of any of the congeners of the brominated dibenzofurans were not available in the literature as cited in the Appendix. The lack of appropriate data precludes the derivation of a q_1^* or ADI.

The only toxicity data available described a single lethal dose of 2,3,7,8-tetrabromodibenzofuran in guinea pigs. The lethal dose of ~10 µg/kg and the symptoms of toxicity (see Section 5.6.) were similar to that reported for 2,3,7,8-tetrachlorodibenzofuran. The described symptoms of toxicity were also consistent with acute exposure to lethal doses of 2,3,7,8-TCDD, although the reported lethal dose was 5- to 15-fold lower than that reported for the 2,3,7,8-tetrabromodibenzofuran.

The limited data base suggests that the brominated dibenzofurans would be toxicologically similar to the polychlorinated dibenzo-p-dioxins qualitatively but not quantitatively . These similarities would be consistent with the receptor-mediated mechanism of toxicity (Poland et al., 1976; U.S. EPA, 1984) for the polychlorinated dibenzo-p-dioxins and other compounds with similar structures such as the brominated dibenzofurans. The similarities in structure, the positive results in carcinogenicity and teratogenicity bioassays, and the low levels which result in frank effects in reproductive and chronic toxicity studies of some of the congeners of the polychlorinated dibenzo-p-dioxins (especially 2,3,7,8-TCDD) indicate that some of the analogous congeners of the brominated dibenzofurans may be highly toxic and carcinogenic when tested. However, the data base is too limited to allow for an accurate extrapolation at this time.

9. REPORTABLE QUANTITIES

9.1. REPORTABLE QUANTITY (RQ) RANKING BASED ON CHRONIC TOXICITY

Subchronic and chronic studies of the brominated dibenzofurans were not located in the available literature as cited in the Appendix; therefore, derivation of an RQ is precluded (Table 9-1).

9.2. WEIGHT OF EVIDENCE AND POTENCY FACTOR ($F=1/ED_{10}$) FOR CARCINOGENICITY

Studies of the carcinogenic potential of the polybrominated dibenzofurans were not located in the available literature as cited in the Appendix; therefore, the derivation of the potency factor is precluded. According to the newly proposed EPA guidelines, these compounds would be place in group D; that is, for this group of chemicals the available data are inadequate to assess their carcinogenic potential (U.S. EPA, 1984). It should be noted, however, that related compounds, 2,3,7,8-TCDD and a mixture of 1,2,3,6,7,8- and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxins, are animal carcinogens and that epidemiologic data also indicate the possibility that 2,3,7,8-TCDD is a human carcinogen (U.S. EPA, 1984b).

TABLE 9-1

Polybrominated Dibenzofurans

Minimum Effective Dose (MED) and Reportable Quantity (RQ)

Route:	
Dose:	
Effect:	
Reference:	
RV_d:	
RV_e:	
Composite Score:	
RQ:	Data are not sufficient for deriving an RQ.

10. REFERENCES

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APPENDIX

LITERATURE SEARCHED

This profile is based on data identified by computerized literature searches of:

CA SEARCH (Files 308, 309, 310, 311, 320
TOXLINE
RTECS
OHM TADS
STORET
SRC Environmental Fate Data Bases
SANSS
AQUIRE
TSCAPP

These searches were conducted in March, 1985. In addition, hand searches were made of Chemical Abstracts (Collective Indices 6 and 7), and the following secondary sources were reviewed:

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In addition, approximately 30 compendia of aquatic toxicity data were reviewed, including the following:

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